UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE - RESEARCH

in cooperation with the

Minnesota Agricultural Experiment Station
and the
St. Anthony Falls Hydraulic Laboratory

MODEL STUDIES
FOR
WHITING FIELD NAVAL AIR STATION
MILTON, FLORIDA

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STRAIGHT DROP SPILLWAY

by

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St. Anthony Falls Hydraulic Laboratory
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Report No. MN-R-3-37
July 1949

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Straight Drop Spillway, Structure B-6

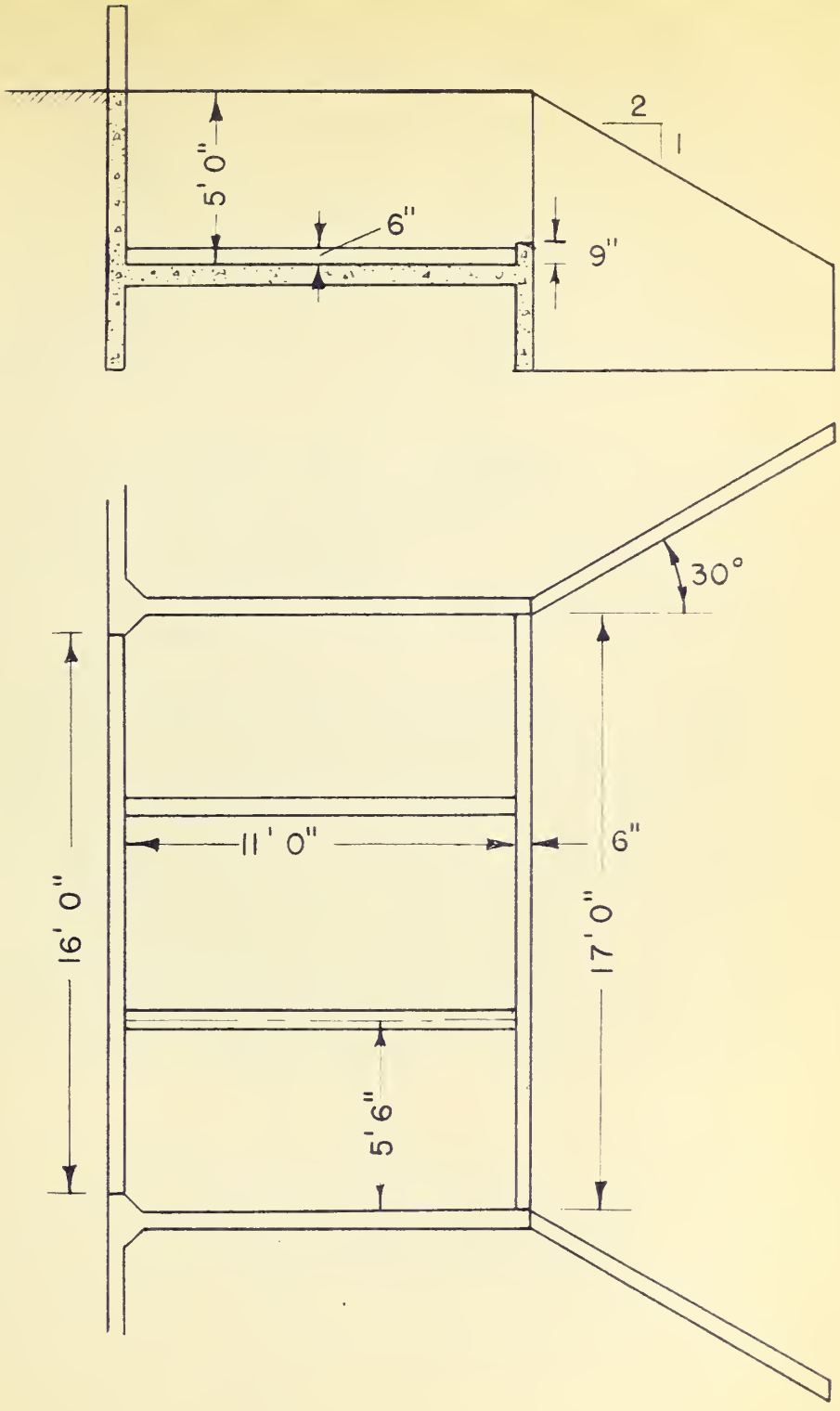
The purpose of this report is to discuss tests made on a straight drop spillway and its energy dissipator, and to present a design of energy dissipator for use in B Ditch at the Whiting Field Naval Air Station, Milton, Florida. The particular structure on which tests were made is designated B-6. The studies reported here cover but one phase of the model investigation required for the proper design of a storm-water disposal system at Whiting Field. These studies were authorized by Mr. Lewis A. Jones, Chief, Division of Drainage and Water Control, Soil Conservation Service Research, on September 20, 1948. The tests are summarized in an appended table.

Many spillways of the Morris-Johnson* type have been constructed of sheet steel piling at Whiting Field, and a large number of these structures have failed to function satisfactorily. Tests of this particular type of structure were desired in order to insure that the new structures needed would adequately perform their intended function. The soils in this area are readily erodible, and well designed structures are required in order to insure their permanence.

Morris-Johnson Design

A one-twelfth size model of the Morris-Johnson straight drop spillway on which tests were made is shown in Figure 1. The prototype design discharge is 176 cfs, and the head over the 16-foot wide by 2.5-foot deep notch is 2 feet. The stilling basin has a width of 17 feet, a length of 11.5 feet, end sills 0.75 feet high, and longitu-

*Morris, B. T. and Johnson, D. C, "Hydraulic Design of Drop Structures for Gully Control," TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS, Volume 108, pp. 887-940, 1943.



MORRIS-JOHNSON DROP SPILLWAY

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Figure 1

dinal sills 0.5 feet high located 5.5 feet from either side of the basin. The drop from the crest of the weir notch to the basin floor is 5 feet. The wingwalls have a 1 on 2 top slope and flare at an angle of 30 degrees with the centerline. The approach channel is 16 feet wide and has 1 on 3 side slopes. Its centerline is laid out on a curve having a 75 foot radius. The exit channel is 18 feet wide and has 1 on 3 side slopes. This model installed in the test channel is shown in Figure 2.

The first test showed that the location of the spillway at the end of the horizontal curve is undesirable since the main flow is directed across the spillway structure and into the far bank of the exit channel. This can be seen in Figure 3a. The scour pattern is also unsymmetrical, as can be seen in Figure 3b. In order to improve the approach conditions, the location of the structure was moved downstream 36 feet beyond the end of the horizontal curve. Flow conditions are shown in Figure 4a and the scour pattern in Figure 4b. The maximum depth of scour occurred near the wingwalls where it was 3.5 feet below the top of the end sill. The scoured material was deposited in the center of the downstream channel. This forced the low flows to follow along the banks where they may damage them, which caused considerable concern since trouble had been experienced at Whiting Field because of bank erosion and stream meandering. There was no scour behind the wingwalls.

The design tailwater depth is 2.5 feet. This was raised to 3.5 feet in an effort to reduce the scour and the deposit in the center of the channel. The scour was reduced from 3.5 feet to 2.0 feet, but an excessive amount of material was still deposited in the center of the channel. It was not only the volume of the deposit but also its location that caused concern.

In an effort to cut down the volume of the scour and subsequent deposit, the bed of the downstream channel was lowered 1.5 feet for a distance of 20 feet beyond the end of the basin. The tailwater depth was 3.5 feet over the basin end sill. Scour to a depth of about 3

FIGURE 2

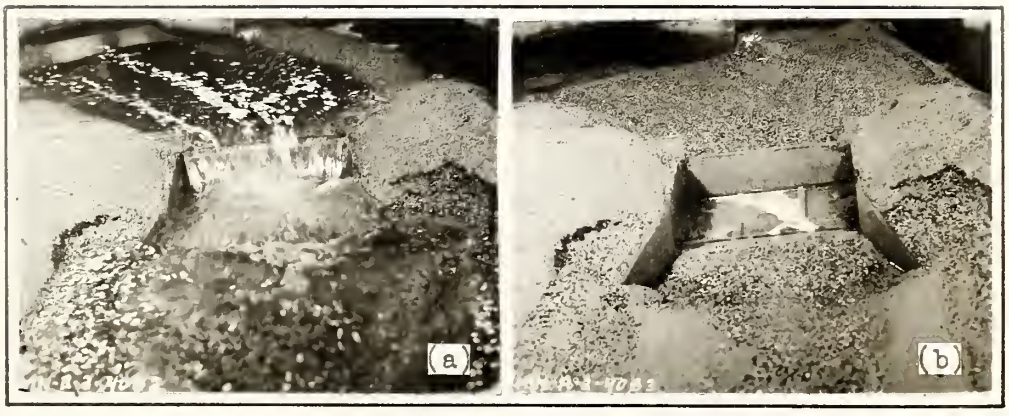


FIGURE 3

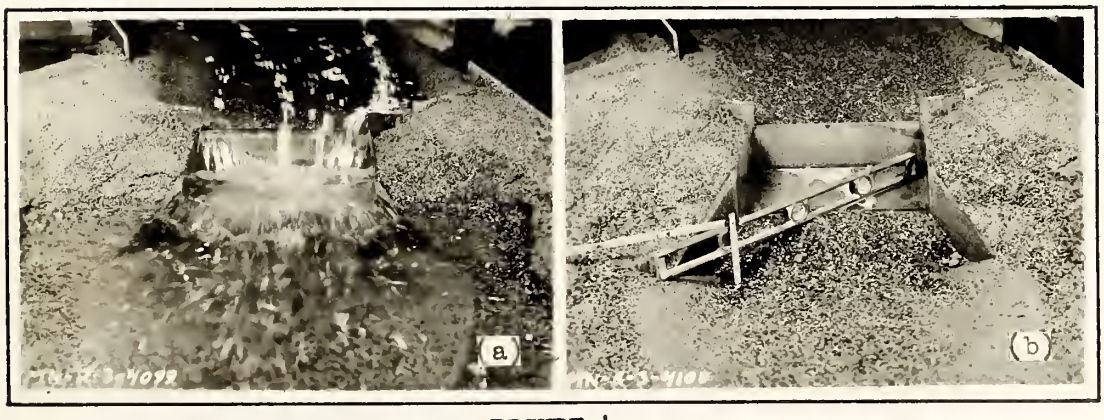


FIGURE 4

feet below the top of the end sill occurred near the wingwall as can be seen in Figure 5. However, most of the scoured material was deposited in the excavation, and little material was deposited above the grade of the channel bed. This treatment of the Morris-Johnson spillway design gave the best results; that is, increasing the tailwater depth and overexcavating the downstream channel.

Straight wingwalls were tried during the investigation of this spillway, but they did not reduce the scour or the deposits in the downstream channel.

During the tests scour was observed above the spillway near the ends of the notch. This scour, which is shown in Figure 6, is caused by whirls and a downward and inward movement of water along the headwall. A test with the headwall located at an angel of 60 degrees with the channel centerline did not reduce the scour. It was finally decided that the most economical means of preventing scour at this location would be to protect the bed and banks. The channel bed should be protected for a minimum 5-foot radius from the ends of the weir and the banks of the approach channel should be protected for a minimum of 5 feet upstream from the headwall extension.

Wisconsin Notch Spillway

The engineer in charge of the design of this spillway was not completely satisfied with the results obtained with the Morris-Johnson design. He therefore submitted a design based on the notch spillway described by Kessler*. The stilling basin has a length of 13 feet and a width of 17 feet. Two transverse sills were used in this basin, the upstream sill being 7 feet from the weir and 1.0 foot high, and the downstream sill being 11 feet from the headwall and 8 inches high. The wingwalls were the same as those used for the Morris-Johnson

*Kessler, Lewis Hanford, "Experimental Investigations of the Hydraulics of Drop Inlets and Spillways for Erosion Control Structures," Bulletin of the University of Wisconsin, Engineering Experiment Station Series No. 80, pp. 47-50, 1934.

FIGURE 5

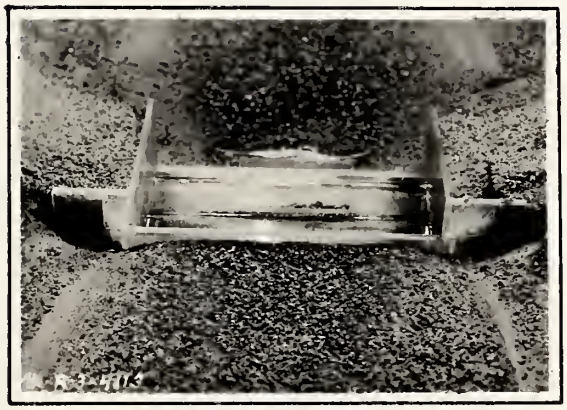


FIGURE 6

design. This outlet is shown in Figure 7. The tailwater used was 2.5 feet over the top of the end sill.

It can be seen in Figure 8a that the nappe hits the outlet floor upstream from the upper sill and that the stream then bounces into the air and lands on the stream bed just beyond the downstream sill. The depth of scour shown in Figure 8b is 3.12 feet--it would have been greater but the floor of the test channel was exposed at that depth.

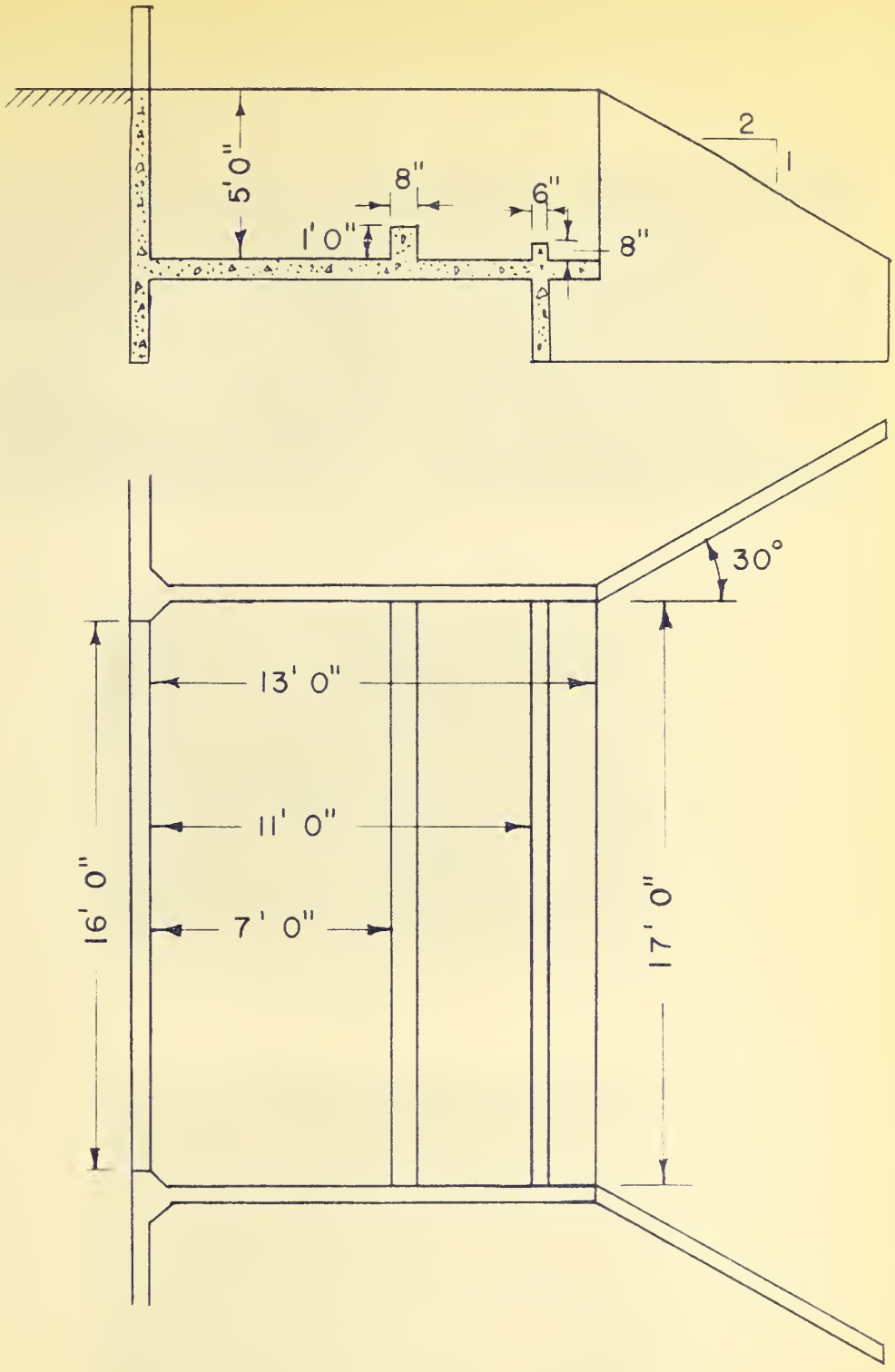
It was obvious that the Wisconsin notch spillway design was unsatisfactory. However, before abandoning it a test was made using the longitudinal sills shown in Figure 9. Although the longitudinal sills improved the performance of this outlet, the depth of scour reached 3.12 feet and again exposed the floor of the test channel.

Development of Whiting Drop Spillway Outlet

In an attempt to improve the performance of the Wisconsin stilling basin, the longitudinal sills and the upstream transverse sill were removed and two rows of blocks were substituted for them. The first row of blocks was located 5 feet from the weir and the second row 3 feet further downstream. The blocks were 1 foot high, 1 foot wide and spaced 1 foot apart. The second row of blocks was staggered with respect to the first row. This arrangement is shown in Figure 10. The rest of the structure was not changed. When this model was tested the flow from the basin was found to be satisfactory, the depth of scour was only 1 foot below the top of the end sill, and the erosion pattern was good.

For the next test the basin was shortened from 13.0 feet to 11.5 feet, making it the same length as the Morris-Johnson basin. No change in the flow conditions or erosion resulted from this reduction in basin length.

Observation of the basin performance indicated that the upstream row of blocks was of little value so the block system was changed to



WISCONSIN NOTCH SPILLWAY

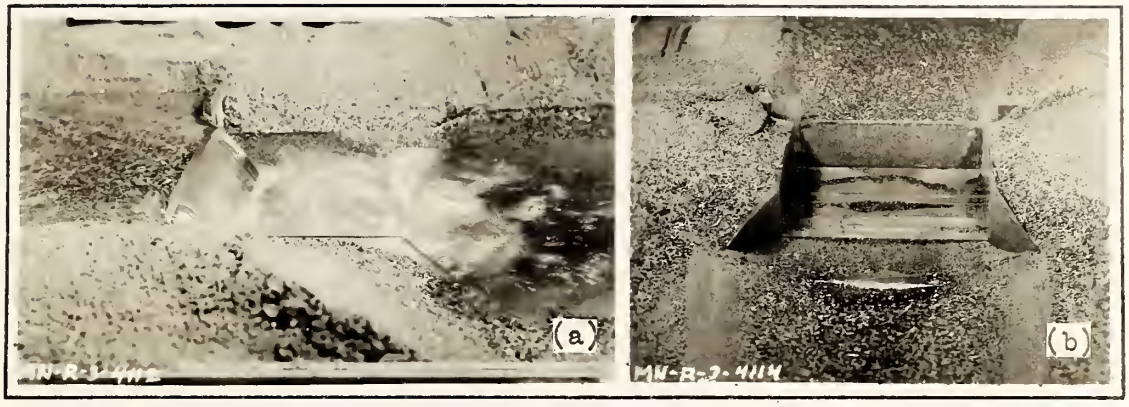


FIGURE 8

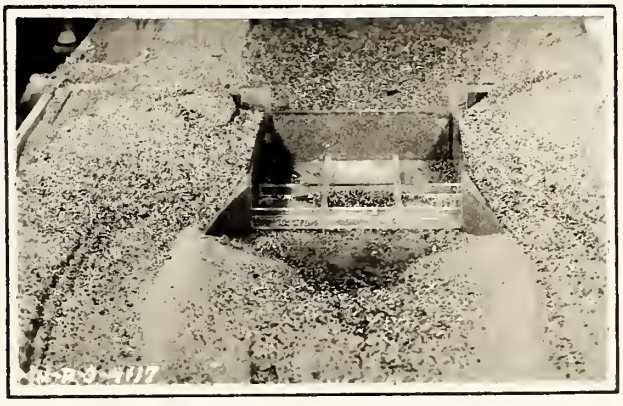


FIGURE 9

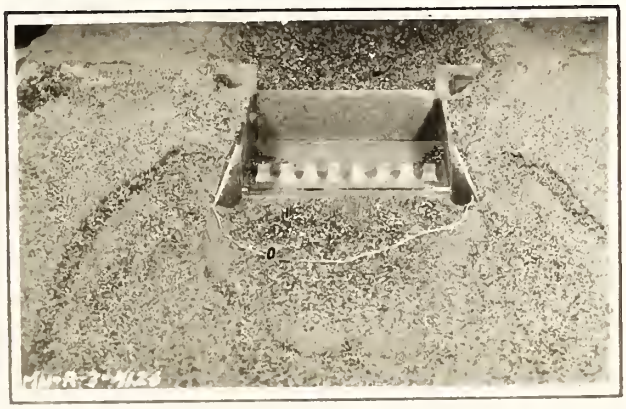


FIGURE 12

a single row of blocks located 7 feet from the weir. As can be seen in Figure 11a and 11b, the basin performance was good with this arrangement. The depth of scour was 1 foot and the scour pattern was satisfactory.

The only other change made in this stilling basin was to substitute a wingwall having a 1 on 1 top slope for the 1 on 2 top slope used until that time. The change was made for reasons of construction economy. The scour pattern is shown in Figure 12 and is almost identical with that obtained previously. The maximum depth of scour is 1.0 foot below the top of the end sill, or 4 inches below the basin floor elevation. The scour pattern is good. No scour occurs behind the wingwalls, although a little wavewash is noted along the water line.

Recommendations

The recommended proportions of this straight drop spillway are shown in Figure 13 for the design discharge of 176 cfs and a tailwater depth over the end sill of 2.5 feet. It is also recommended that some protection be provided for the bed and banks upstream from and near the ends of the spillway. The minimum area requiring protection is shown in Figure 13.

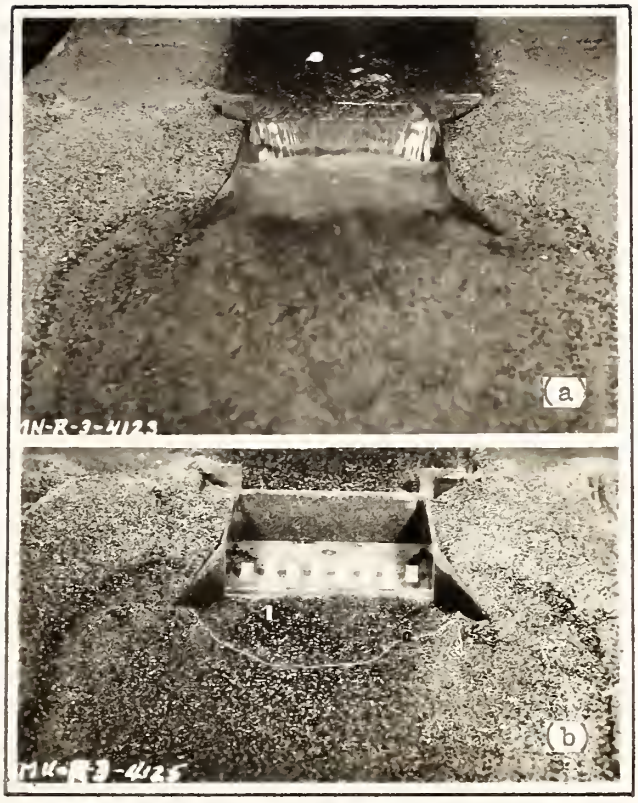


FIGURE 11

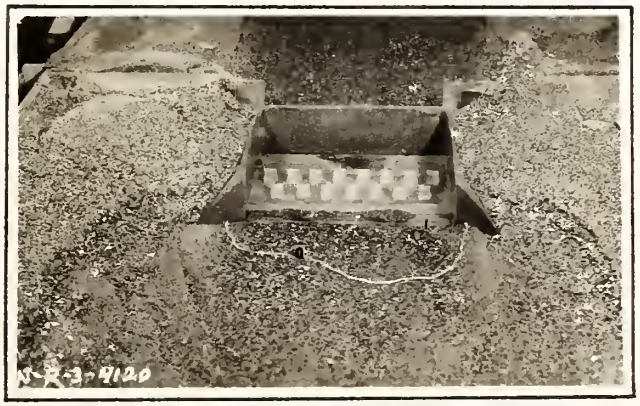
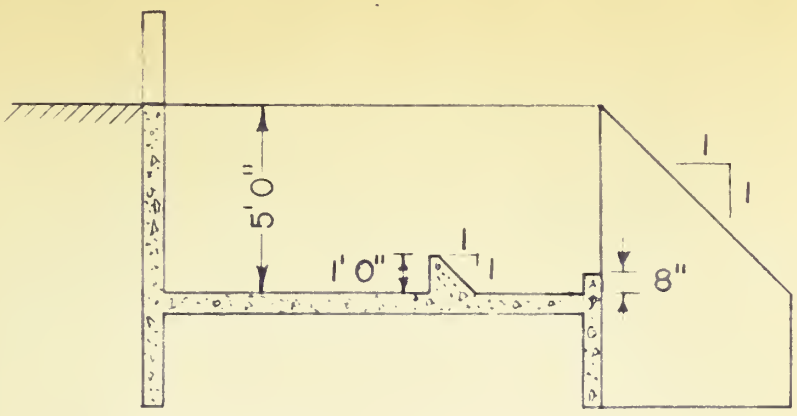
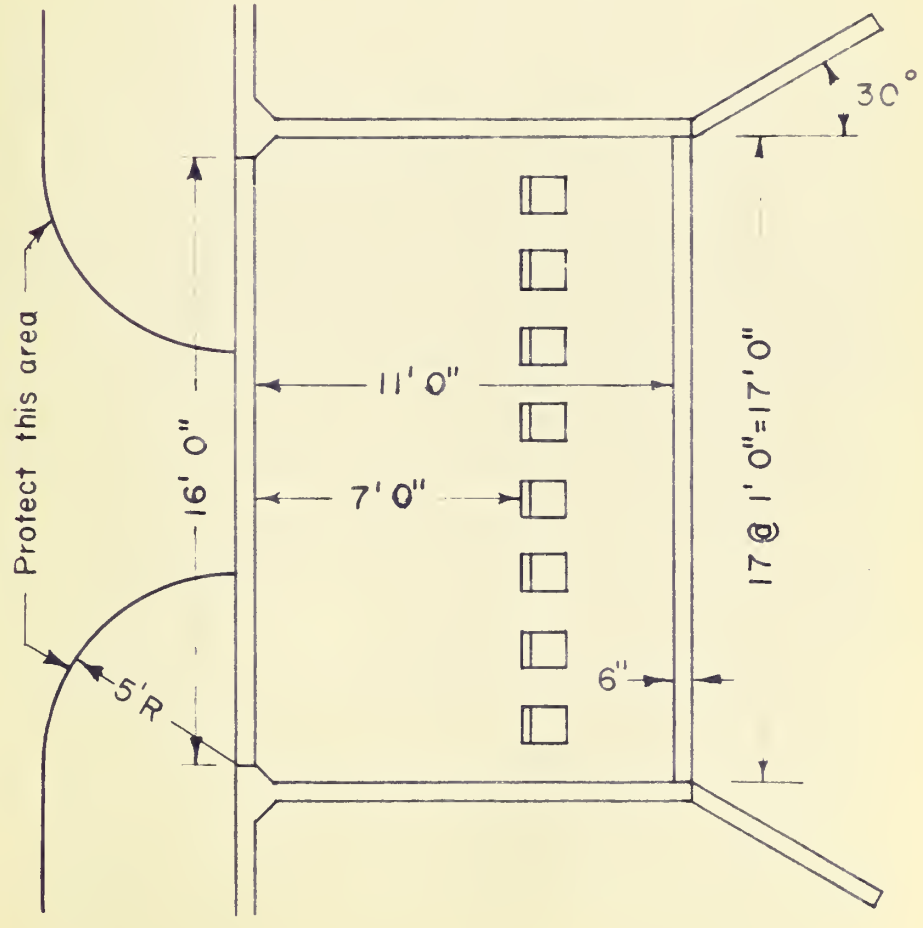


FIGURE 10





STRAIGHT DROP SPILLWAY OUTLET
FOR
WHITING NAVAL AIR STATION

SUMMARY OF TESTS

Test No.	Type of Basin	Basin Length ft.	Q cfs	H ft.	Basin Blocks and Sills: Type	Basin Blocks and Sills: Height ft.	End Sill Height ft.	Tailwater Depth ft.	Wingwall: Top Slope	Wingwall: Angle to Centerline degrees	Maximum[a] Erosion ft.	Location of Maximum Erosion
1	Morris-Johnson[b]	11.5	176	2	Longitudinal sills	0.5	0.75	2.5	1 on 2	0	3.5	Near wingwall
2	Morris-Johnson[c]	11.5	176	2	Longitudinal sills	0.5	0.75	2.5	1 on 2	0	3.75	Near wingwall
3	Morris-Johnson	11.5	176	2	Longitudinal sills	0.5	0.75	2.5	1 on 2	30	3.5	Near wingwall
4	Morris-Johnson	11.5	176	2	Longitudinal sills	0.5	0.75	3.5	1 on 2	30	2.0	Near wingwall
5	Morris-Johnson[d]	11.5	176	2	Longitudinal sills	0.5	0.75	3.5	1 on 2	30	3.0	Near wingwall
6	Wisconsin Notch Spillway	13.0	176	2	Transverse sills	1.0	0.67	2.5	1 on 2	30	3.12[e]	On centerline 8' out[f]
7	Wisconsin Notch Spillway	13.0	176	2	Transverse and longitudinal sills	1.0	0.67	2.5	1 on 2	30	3.12[e]	On centerline 8' out[f]
8	Design 1[g]	13.0	176	2	Two rows of blocks	1.0	0.67	2.5	1 on 2	30	1.0	On centerline 2' out[f]
9	Design 2[g]	11.5	176	2	Two rows of blocks	1.0	0.67	2.5	1 on 2	30	1.0	On centerline 2' out[f]
10	Design 3[g]	11.5	176	2	One row of blocks	1.0	0.67	2.5	1 on 2	30	1.0	On centerline 2' out[f]
11	Final Design[g]	11.5	176	2	One row of blocks	1.0	0.67	2.5	1 on 1	30	1.0	On centerline 2' out[f]

[a] Below top of end sill. [b] Headwall located at 60° angle to channel centerline. [c] Recommended design conditions. [d] Channel bottom excavated 1.5 feet below grade. [e] Bottom of tost channel exposed. [f] Beyond end of basin. [g] Whiting Straight Drop Spillway.